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ABSTRACT

To determine whether children's knowledge of arithmetic facts becomes increasingly "automatic" with age, 7-year-olds, 11-year-olds, and adults were given a number-matching task for which mental arithmetic should have been irrelevant. Specifically, students were required to verify the presence of a probe number in a previously presented pair (e.g., 5+1 followed by 5). Eleven-year-olds and adults were slower to reject a probe that was the sum of the initial pair (e.g., 5+1 and 6) than to reject a probe that was not the sum (e.g., 5+1 and 3). This finding indicates that, in older children and adults, obligatory activation of a sum interferes with a required response. No evidence for obligatory activation was found for 7-year-olds. These results tend to be consistent with current models of arithmetic knowledge, and they suggest that one aspect of the development of arithmetic skill is the automatic retrieval of stored facts. (Author/TW)

Cognitive Arithmetic: Evidence for the Development of Automaticity

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ABSTRACT

To determine whether children's knowledge of arithmetic facts becomes increasingly automatic with age, 7-year-olds, 11-year olds, and adults were given a number-matching task for which mental arithmetic should have been irrelevant. Specifically, students were required to verify the presence of a probe number in a previously presented pair (e.g. 5 + 1 followed by 5). 11-year-olds and adults were slower to reject a probe that was the sum of the initial pair (e.g., 5 + 1 and 6) than to reject a probe that was not the sum (e.g., 5 + 1 and 3) at short stimulus onset asynchronies. This finding indicates that, in older children and adults, obligatory activation of a sum interferes with a required response. No evidence for obligatory activation was found for 7-year-olds. These results are consistent with current models of arithmetic knowledge and suggest that one aspect of the development of arithmetic skill is the increasingly automatized retrieval of stored facts.

INTRODUCTION

Current theories of the representation of arithmetic knowledge are based on models of word representation in semantic memory (Ashcraft, 1982, 1987). Numbers are represented as nodes in a network and connected via associative links to related nodes such as sums. The retrieval of a sum occurs when activation spreads from the addends to all connected nodes. According to the assumptions of a network representation, the spread of activation is automatic in that it occurs without intention (Collins & Loftus, 1975; Neely, 1977).

One implication of a semantic network model for development is that retrieval is expected to become increasingly automatic or obligatory (Siegler, 1986; Ashcraft, 1987). Older children and adults have had extensive experience using retrieval to solve simple arithmetic problems. Young children, however, have had less opportunity to develop efficient retrieval mechanisms. If the development of arithmetic knowledge is characterized by the creation of an interconnected network of facts, then one aspect of developmental change should be the increasingly automatized retrieval of connected nodes.

METHOD

In the present study, a number-matching task was used to examine the development of automatic activation of arithmetic facts (see also LeFevre, Bisanz, & Mrkonjic, in press, for details of the procedure). Seven-year-olds, eleven-year-olds, and adults solved number-matching problems, as shown in Table 1. A pair of numbers was presented (e.g., "5 + 1") and then, after a variable delay, a probe number appeared. Students were to respond "yes" if the probe

matched a number in the initial pair (e.g., "5") or "no" if the probe did not match (e.g., "3"). On half of the "no" trials, the probe was the sum of the initial pair (e.g., "6"). If a sum is activated without intention upon presentation of a number pair, then it should take subjects longer to reject a sum probe than to reject a neutral probe.

Insert Table 1 about here

The delay between onset of the pair and onset of the probe (stimulus onset asychrony or SOA) was also varied. In similar studies done with words, subjects were able to inhibit the activation from related nodes when it was not helpful for the task, but only after relatively long SOAs (Neely, 1977). In the present task, the activated sum node makes the decision about the presence or absence of the probe more difficult. At longer delays, subjects may be able to avoid the interfering effect of the sum, or the activation may decay. Therefore, we expected an interaction between SOA and problem type, specifically, that interference would be largest at a relatively short SOA.

RESULTS

Eleven-year-olds and adults rejected Sum items more slowly than Neutral items, and the difference was only significant at the 120-ms SOA (see Figures 1 and 2). Therefore, for the older children and adults, automatic activation of a sum interfered with the required response in this number-matching task. Younger children, however, did not show evidence for obligatory activation. For the

seven-year-olds, there was no significant difference in latencies to Sum and Neutral items. These results are consistent with the view that one aspect of the development of arithmetic skill is the increasingly efficient retrieval of stored facts.

Insert Figure 1 about here

Insert Figure 2 about here

CONCLUSIONS

(1) These results support a semantic network model of arithmetic knowledge, in which numbers are represented as nodes in a network and accessed via spreading activation.

(2) One aspect of the development of arithmetic skill may be the increasingly efficient and automatic retrieval of stored facts.

(3) These data are consistent with the notion that number knowledge is represented similarily to word knowledge and accessed via similar mechanisms. Identification of parallels between different content domains is crucial to a complete understanding of the development of human cognitive processes.

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TABLE 1

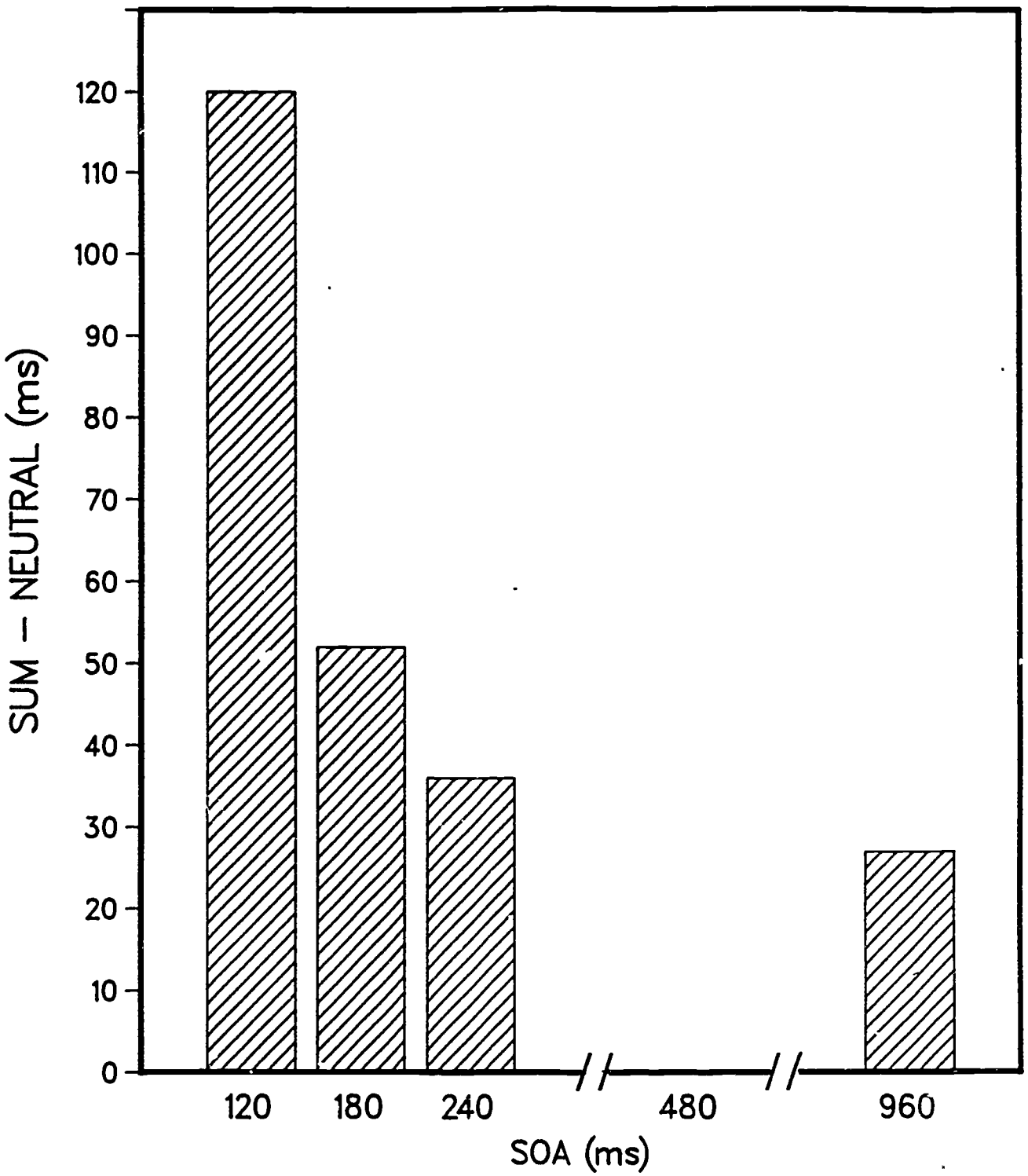
Initial Pair	Probe	Response	Problem Type
5 + 1	5	yes	match
5 + 1	3	no	neutral
5 + 1	6	no	sum

Stimulus Onset Asynchronies (SOAs):

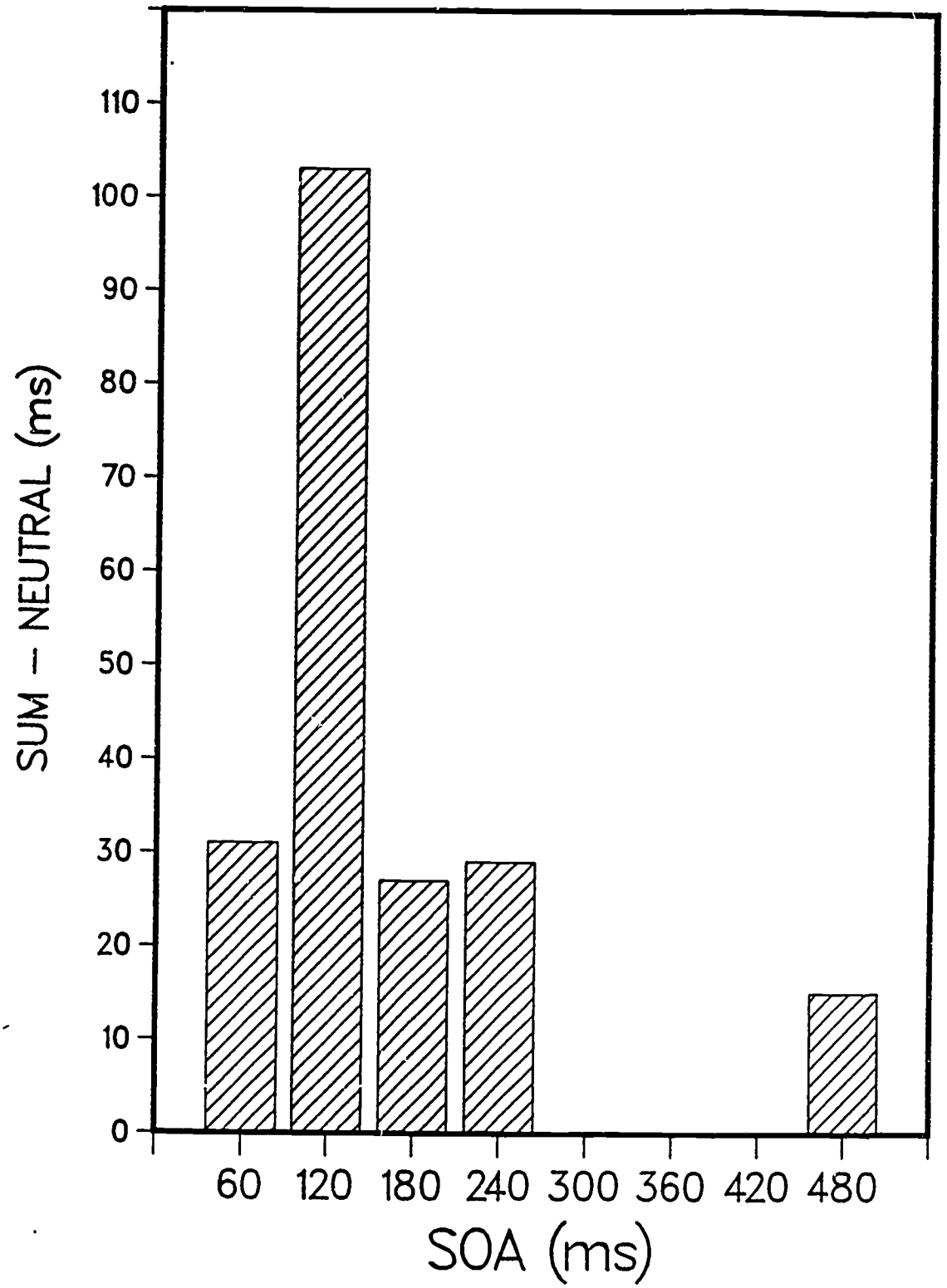
Children: 120, 180, 240, 480, and 960.

Adults: 60, 120, 180, 240, and 480.

11-YEAR-OLDS


SUM – NEUTRAL (ms)
120
110
100
90
80
70
60
50
40
30
20
10
0
120
180
240
480
960
SOA (ms)

ADULTS


SUM – NEUTRAL (ms)
110
100
90
80
70
60
50
40
30
20
10
0
60
120
180
240
300
360
420
480
SOA (ms)